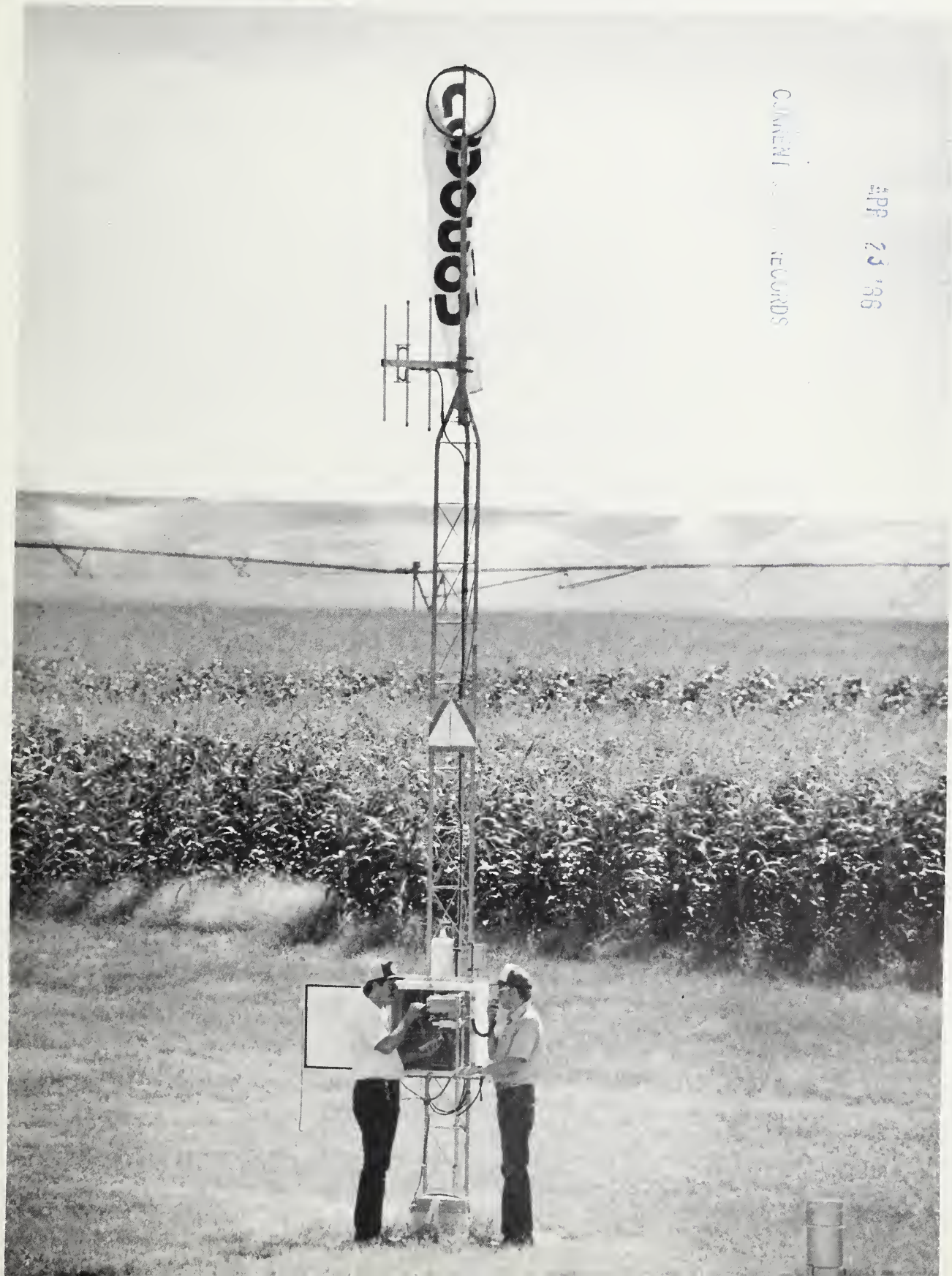
U.S. Department of Agriculture • Agricultural Research Service
March 1984

Agricultural Research



Calories and the Human Internal Combustion Engine

Why do some people deposit fat while others, who consume the same number of calories and expend the same amount of energy, look like Twiggy? That's just one question that will be put to one of the world's most advanced human calorimeters currently being installed at Beltsville, Md. According to C.E. Bodwell, chief of the Protein Nutrition Laboratory, who is overseeing its installation, "It will be the only room-sized calorimeter in the United States dedicated to human studies, and one of the few times direct calorimetry and indirect calorimetry will be combined in one operation."

Simply put, a human calorimeter is a chamber that measures the heat a body produces during various activities—which translates to the energy required for those activities and the relative efficiency with which different foods are used in providing that energy.

When the Beltsville calorimeter begins producing results in 2 to 3 years, it will mark nearly 100 years since Wilbur O. Atwater—the father of American nutrition—began the first calorimetry studies in the United States, and more than two centuries since the science of nutrition got off to a slow but sure start.

In the early 1780's, the French chemist Antoine Lavoisier advanced the revolutionary theory that combustion was the combination of oxygen with substances. Hydrogen, oxygen, nitrogen, and carbon dioxide had only recently been discovered. He then went on to measure body heat produced, oxygen consumed, and carbon dioxide released and concluded that respiration was a form of combustion—internal combustion. He also found that working man expended more energy than resting man and therefore needed more food.

His experiments pointed the way to calorimetry, but chemistry had not yet advanced to the stage that made this possible. In fact, about 30 years passed before his fellow countryman, Francois Magendie, identified nitrogen-containing foods as necessary for life. Another 18 years passed before a London physician, William Prout, theorized that food contained three "staminal principles," which he called saccharine, oily, and albuminous—now known as carbohydrate, fat, and protein.

By the 1840's, the renowned German chemist, Justus von Liebig, had turned his attentions toward agricultural chemistry and began calculating the energy contained in some foodstuffs. One of his students, Carl Voit, together with Liebig's assistant, built the first human calorimeter some 20 years later. His studies laid the foundation for determining human nutritional requirements.

While Voit studied human metabolism and respiration in Munich, Atwater analyzed corn fodder for his doctoral thesis at Yale University. Atwater then set out to study in Germany—the hotbed of chemistry—and returned impressed with the European system of experiment stations. He "settled down" in Middletown, Conn., as chemistry professor at his alma mater, Wesleyan University. Two years later, in 1875, he donned a second hat as the first director of the first U.S. agricultural experiment station at Storrs, Conn. Here, for the next 14 years, he continued research on the composition of feeds and began to explore the composition of human food.

In 1887, Atwater was again in Europe, this time to study human calorimetry with Carl Voit. He returned to Middletown in 1888 to organize and direct USDA's new Office of Experiment Stations which had been established the previous year by the Hatch Act—a goal Atwater had long lobbied for. His idea was to use the federal Office to link states, private agencies, and federal laboratories in cooperative research. The earliest of these studies were surveys showing what people in different areas of the country actually ate.

Concurrently, Atwater set about building a human calorimeter with his colleagues at Wesleyan—E. B. Rosa and F. G. Benedict. While college students took exams, pedaled a stationary bike, and did other work with mind and muscle in the copper-lined chamber, Atwater studied their metabolism and the quantity of energy spent. These studies led to the energy values of 4,9,4 kilocalories per gram of carbohydrate, fat, and protein still widely used by nutritionists and dietitians to plan meals. They also provided a clear blueprint for future nutrition studies.

Atwater resigned as director of the Office of Experiment Stations in 1891, but his activism for American nutrition was far from over. He rallied 16 chemists with full equipment to prepare and analyze food before a wide-eyed public at the Chicago World Fair in 1893. The demonstrations generated enough interest and publicity to spur Congress to appropriate the first federal funds—a sum of $10,000—to study the nutritive value of foods and to recommend "full, wholesome, and edible rations less wasteful and more economical than those in common use." Atwater used the funds to orchestrate a research effort that encompassed colleges, experiment stations, public institutions, and private organizations. The result of this collective effort was Farmers Bulletin No. 28—the first comprehensive table of food composition in the United States and the first of a long series of food tables issued by the USDA.

The science of nutrition has come a long way since Atwater's pioneering studies, but science sometimes must keep pace with progress. "We don't know the energy requirements of today's men and women who spend more time behind a desk than their forebears," says Bodwell. Furthermore, the foods we eat today in the United States are far different from those consumed even a generation ago, he explains, naming modified starch products and high-fiber breads as examples. "We don't know how much these foods differ in their energy content from the standard turn-of-the-century fare, but we suspect they do." The Beltsville calorimeter should settle these questions.

J.L.M.

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Cover: This weather station is part of an ARS-designed, computer-operated, sprinkler irrigation system that enables growers to meet the water needs of growing crops, yet pay lower electric rates by curbing irrigation during periods of peak power demand. The experimental system is installed on the Condon Ranch near Sterling, Colo. This is just one of three reports on the ways technology is revolutionizing irrigated agriculture. Article begins on p. 8. (0983X1223-34)

Colorless Alga Can Pollute Water, Cause Mastitis

Veterinary medical officer John S. McDonald compares the 75-percent reduction in milk production from a mammary gland infected with mastitis caused by the alga, *Prototheca,* to the output from normal glands. (0983X1130-20A)

There exists a green alga that lost its color and now barely survives in water. But it thrives in sewage, animal wastes, and tree-wound drainage, and can infect man and animals, especially cows. It is the only alga known to cause disease in mammals.

Prototheca, a colorless alga often mistaken for a yeast, is a cause of mastitis in dairy cows. In February 1983, the first case recognized in Iowa was reported by John S. McDonald, veterinary medical officer, John L. Richard, microbiologist, and Norman F. Cheville, pathologist, at the ARS National Animal Disease Center, Ames, Iowa.

Because mastitis can be caused by yeasts, bacteria, colon bacilli, and other microorganisms, and because of the colorless alga's yeast-like appearance, *Prototheca* may have been misdiagnosed or overlooked in the past.

"If we had been trying to diagnose the cause of mastitis in the past, we might have seen more *Prototheca* infection," says McDonald. "Most veterinary diagnostic laboratories probably would call *Prototheca* mastitis a yeast infection, and that would be it." Cows with mastitis caused by "unknown yeasts" commonly are culled and the investigation ends, McDonald explains.

The alga is "either causing more mastitis or being identified more frequently," McDonald continues. "I think we may be getting a buildup of this organism. We're handling many more cows in much less space. *Prototheca* may be one of those organisms that can build up where there is a high population of animals. It's a moisture-loving organism. It survives well in wet or damp areas and in feces. I think this is one reason we are seeing more and more cases."

In the United States, *Prototheca* mastitis was detected and first reported in Wooster, Ohio, in 1969. It had previously been found in parts of Europe, South Africa, and Canada. In 1982, more than 400 cases were reported in New York. According to McDonald, numerous isolations also have been made from infected dairy cows in California, Minnesota, and Wisconsin.

In the case of the Iowa cow, Richard identified *Prototheca zopfii* as the organism McDonald isolated from the animal. The dairyman had culled her from his herd because she had mastitis that would not yield to treatment.

"Whenever we find a yeast," McDonald says, "and I thought this was a yeast, I send it to John [Richard]. I couldn't do a study like this by myself. The interactions of a microbiologist, a pathologist, and a veterinarian made this study possible."

The scientists studied the Iowa case for 12 weeks. Then laboratory experiments with two artificially infected cows produced additional information on the overall effects, the release of algal cells from mammary glands, and the spread of infection to other tissues.

They found that both naturally and experimentally infected cows had normal temperatures and appetites. Mastitis was mild. Infected quarters yielded watery secretions and clots, produced less milk than uninfected glands, and remained firmer after milking. Richard recovered *Prototheca* cells from milk samples from infected quarters, and McDonald determined that the alga survives only 15 seconds in milk at 143°F (62°C), the temperature of pasteurization.

At postmortem, pathologist Cheville found rough, inflamed tissues in infected glands, but normal tissues in other organs. Some algal cells found in the infected tissues appeared to lack nuclei and cytoplasm—cell components that are normally present. Cheville says that both "empty cells" and intact cells were within macrophages. Macrophages are cells, produced by the cow in this instance, that engulf foreign materials such as the algal cells to protect the cow.

It appears, however, that *Prototheca* reproduced within the macrophages. Richard says the macrophage and the alga's own wall "may protect it from more potent body defenses and antimicrobial agents."

This protection has an unfortunate side effect. "Once a cow gets mastitis due to *Prototheca*," McDonald says, "there's only one thing to do. Cull and send her to slaughter, because presently there's no effective treatment. *Prototheca* is resistant to nearly all the common antibiotic and antimycotic (antifungal) agents."

The Disease Center scientists tested 25 antimicrobial agents on laboratory cultures of 48 *Prototheca* strains. All strains resisted 19 agents, and only 2 agents demonstrated activity against all strains of the alga.

"Even if therapy would eradicate infection," McDonald says, "extensive damage to the mammary gland, as we observed in our studies, would reduce milk production so much that the previously infected animal would no longer be profitable for the dairy farmer. Some farmers have lost half their herds in culling to eliminate *Prototheca*."

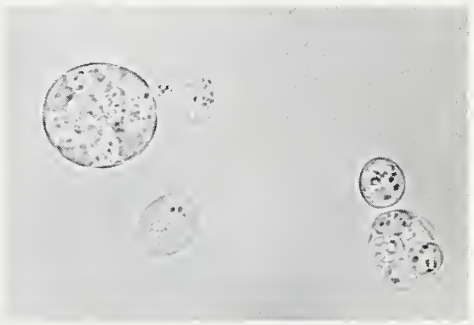
Microbiologist R. Scott Pore of the West Virginia University School of Medicine credits the cell wall of the alga, which is resistant to digestion, with enabling *Prototheca* to pass through the intestinal tracts of humans and animals without multiplying or injuring the host.

"There are no reported instances of communicability," says Pore, who reported the first study of *Prototheca* ecology in 1983, in collaboration with scientists from two private corporations and the U.S. Environmental Protection Agency.

McDonald corroborates that cattle can carry *Prototheca* in the intestinal tract without having mastitis. "It apparently does not cause diarrhea or disease in the intestinal tract," he says, "but it contaminates the environment where cows are held." Pore agrees that "one must assume that infections are of environmental origin."

Perhaps 20 cases of *Prototheca* in humans—skin infections or infections secondary to other diseases—have been reported since the colorless alga was isolated in 1894. Richard says no *Prototheca* infections in humans have been related to drinking milk or handling infected dairy cows. At least one human case recently yielded to treatment with an antibiotic, amphotericin B. Infected skin usually is removed surgically.

Once in a sewage system, *Prototheca* cells apparently multiply, and some escape most treatment methods. "No method except [sludge] incineration completely eradicates *Prototheca*," Pore says.



Top: To help identify *Prototheca*-caused tissue changes within udder cells, pathologist Norman F. Cheville (center), microbiologist John L. Richard (right), and McDonald study micrographs of infected cells. (0983X1132-14)

Above: Photomicrograph of *Prototheca zopfii*, the colorless alga that thrives in sewage and animal wastes, and is the only alga known to cause disease in mammals, especially cows. (PN-7090)

In the ecology studies, *Prototheca* cells did not maintain their population level when added to streams. Even polluted water did not support a high population. "Organic pollution is the key," Pore says. "*Prototheca* cells could be prime candidates as sewage indicator organisms along with fecal bacteria."

John S. McDonald, John L. Richard, and Norman J. Cheville are located at the National Animal Disease Center, P.O. Box 70, Ames, Iowa 50010.—**Dean Mayberry**, Peoria, Ill. ■

Heavy Water Fuels Seed Research

Above: Plant physiologist Lowell Woodstock and biological laboratory technician Linda Braun examine the growth of high-vigor soybean seeds moistened with deuterium oxide (heavy water). (1183X1525-21A)

Above right: In some experiments testing seed vigor, the seed coat is removed to allow the embryonic axis—which grows to form the seedling—to become fully saturated with heavy water. (0983W1239-27A)

Deuterium has had its share of lab jobs. Since its discovery in 1931, this rare, nonradioactive isotope of hydrogen has been employed in research ranging from nuclear collisions to the biological rhythms of algae.

Now ARS research suggests deuterium has a place in the agricultural laboratory. According to Lowell W. Woodstock of the Seed Research Laboratory at the Agricultural Research Center, Beltsville, Md., deuterium can be used to tell good soybean seeds from bad.

Research on deuterium-caused stress is shedding light on the biological basis of seed vigor. The findings, for example, show a unique and previously unknown seed response to stress in terms of membrane permeability and respiratory metabolism. Secondly, they illustrate the importance of seed vitality in determining response to stress. Lastly, they underscore how critical the timing of stress can be when it occurs during germination.

These results might also have a future practical application, according to Woodstock. Heavy water might serve to evaluate seed performance under stress, complementing other tests used to predict field emergence, stand, and yield of crops.

"We are characterizing a new and unique stress for seeds. In the process, we are developing a test for seed quality that scientists, seed companies, and farmers may find useful."

Woodstock's work is part of the Seed Research Laboratory's mission to produce high-quality crop seeds by

understanding the complex physiological, biochemical, and disease factors that affect seed germination, vigor, and dormancy. Estimates suggest that better seed performance under stress could lead to a 10-percent or greater increase in crop harvest. The facility is one of six laboratories within the ARS Plant Genetics and Germplasm Institute.

Twice the mass of ordinary hydrogen, deuterium disrupts the metabolism of germinating seeds by altering the permeability of cellular membranes. It also inhibits oxygen uptake and disrupts the respiratory process, causing more fermentation to occur within the seeds, the ARS scientist says.

Although high-vigor soybean seeds survive such stress without apparent incident, low-vigor seeds die or grow poorly.

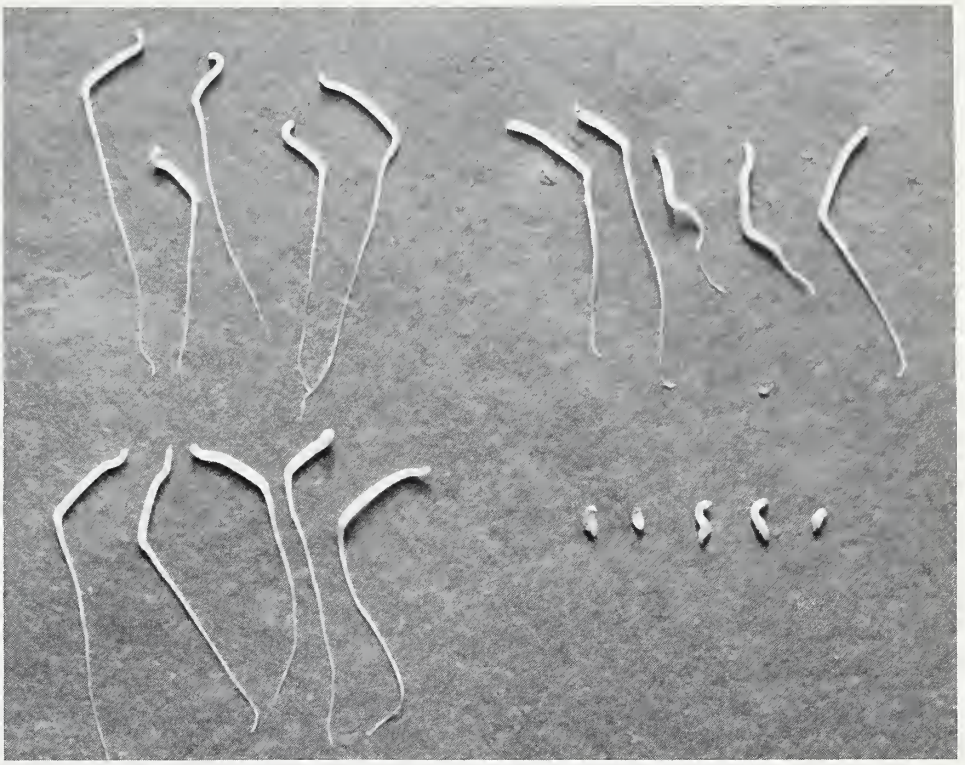
Before Woodstock reached these conclusions, seed response to deuterium oxide (D_2O), or heavy water, was thought related primarily to seed species. Vigor had not been considered.

Experiments at the Seed Research Lab, however, changed all that. Striking differences in both metabolic and germinative responses to D_2O occurred within a single variety of soybean.

"Soybean response to deuterium clearly depended on the vigor or deterioration of the seed," says Woodstock. "Low-vigor seeds could not stand the stress."

In the tests, commercial soybean (*Glycine max* L. Merr. cv 'Essex') seeds were soaked 18 hours at 25°C in D_2O concentrations of 0, 25, 75, and 100 percent. They were then transferred to paper towels moistened with ordinary water (H_20).

The subsequent germination and growth of high-vigor seeds were unaffected by all concentrations of the deuterium oxide. However, low-vigor seeds artificially produced by accelerated aging in the laboratory (4 days at 41°C and 100-percent relative humidity) performed poorly. More than 60 percent of the low-vigor seeds failed to germinate when exposed to 100-percent D_2O. Low-vigor seeds that did germinate grew poorly at 75-percent D_2O and higher. Parallel studies using only the embryonic axes of dry, high- and low-vigor seeds supported the intact-seed data.



Embryos from soybean seeds with high vigor display normal growth whether moistened with regular water (top left) or heavy water (bottom left). Axes from low-vigor soybean seeds also grow well after being moistened with regular water (top right). But the same seed axes show stunted growth when moistened with pure deuterium oxide (bottom right). (1183X1524-22)

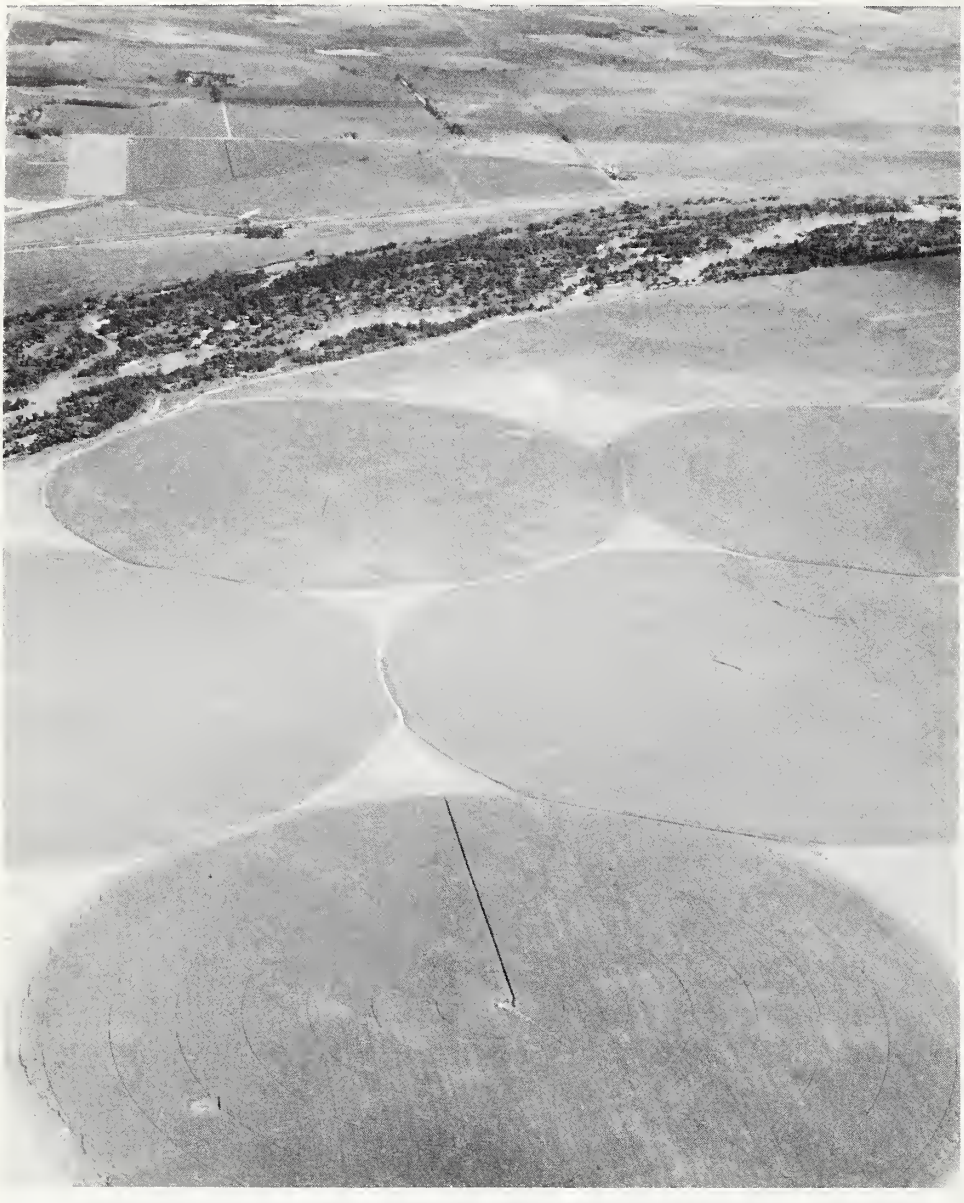
Woodstock is currently working to discover the best moment and length of time to expose germinating seeds and the amount of heavy water needed. Dosage is critical, for deuterium is not cheap. Harmful concentrations of deuterium oxide are not present in nature, so water must be reduced to a one-hundred-thousandth of its original volume to obtain nearly pure D_2O. It sells for $500 a quart.

A little of the rare isotope fortunately will go a long way. When applied after an excised soybean axis has had an initial uptake of water, deuterium oxide concentrations of only 10 to 20 percent can cause the inhibition of axis growth. Furthermore, axes can be saturated with just a few drops of D_2O and then grown on water.

Lowell W. Woodstock is located in Rm. 104, Bldg. 006, Beltsville Agricultural Research Center-West, Beltsville, Md. 20705.—**Andrew Walker**, Beltsville, Md. ■

University of Maryland research assistant Keith Furman examines vessels containing the embryonic axes of soybean seeds in either heavy or regular water. Analysis of their oxygen uptake and fermentation will shed light on the complex relationships between seed vigor, stress timing, stress tolerance, and seed respiration. (0983W1240-33A)

Fine-Tuning Irrigation With Advanced Electronics



Fifteen center-pivot sprinklers, all operated by a master computer, "rain" water onto 150 to 210 acres of corn per pivot at the Condon Ranch near Sterling, Colo. (0983X1212-26)

Irrigation is one area of agriculture that has taken off on the wings of technology. Complex, versatile, yet "user-friendly," the computer is making possible increasingly precise irrigation based on very detailed crop and soil information. Automation by ever lighter and less expensive electronics is pushing the days of manually controlled irrigation into the past. Such precision translates into savings of water, energy, yields, dollars, and time.

Agriculture is the largest single consumer of water in the United States, and irrigated agriculture accounts for more than 61 million acres of farmed land. Research to develop low-cost methods for improving the efficiency of water-distribution systems is, therefore, an ARS priority.

The following article rounds up three recent investigations into ways the new technologies may help sustain and improve the production efficiency of irrigated land while conserving soil and water resources.

Electronic technician Michael C. Blue (left) and Colorado State University engineer Gerald Buchleiter doublecheck the accuracy of weather data that this battery-operated field station reports to the computer every 15 minutes. (0983X1222-10)

To Cut Irrigation Costs—Let the Computer Decide

Scientists have developed a computer system that, on signal from a utility company, shuts down irrigation pumps in specific fields it knows can go without water for awhile.

Dale F. Heermann and fellow ARS agricultural engineer Harold R. Duke, Fort Collins, Colo., built the system around a computer program that is already being used in many areas of the Great Plains for irrigation scheduling.

To qualify for lower electric rates, some growers have been scheduling irrigation in cooperation with utility companies. When power demand nears a peak, the utilities transmit an electronic signal to receivers that control cutoff switches on irrigation pumps.

The new system features a computer that intercepts the cutoff signals and functions as a central control unit. The

..... WEATHER SUMMARY FOR 08/29/83.....

TEMPERATURE MAX.	TEMPERATURE MIN.	TEMPERATURE DWPT.	SOLAR RADIATION	WIND RUN	REF. ET
	deg C		MJ/M*M	KM	MM
37.5	19.3	19.9	22.36	85.6	4.32

.....IRRIGATION SCHEDULE FOR 08/30/83.....

FIELD NAME	CROP USE	RAIN	IRRIGATION	DEPLETIONS START	DEPLETIONS STOP	EARLIEST DATE	LATEST DATE
	MM	MM	MM	MM	MM		
1A	3.30	0.00	0.00	49.3	49.3	08/30	08/30
1B	3.30	0.00	0.00	49.3	49.3	08/30	08/30
2	3.81	0.00	0.00	3.81	7.87	09/04	09/20
3	2.79	0.00	0.00	6.86	6.86	09/03	09/20
4	2.29	0.00	0.00	5.84	5.84	09/03	09/15
5	2.79	0.00	0.00	6.60	6.60	09/03	09/14
6	2.79	0.00	0.00	6.60	6.60	09/02	09/14
7	2.79	0.00	0.00	9.65	9.65	09/03	09/13
8	3.56	0.00	0.00	3.56	3.56	09/03	09/15
9	3.56	0.00	0.00	3.56	3.56	09/03	09/15
10	0.76	0.00	0.00	31.2	12.2	08/30	08/30
11	0.76	0.00	0.00	30.8	19.0	08/30	08/30
12	4.06	0.00	0.00	8.38	8.38	09/03	09/14
14	2.79	0.00	0.00	6.60	6.60	09/03	09/14
15	2.79	0.00	0.00	3.56	6.60	09/02	09/15

THE PRIORITIES FOR LOAD CONTROL ARE:

PRIORITY	FIELD	NO. OF SAFETY HRS.
1	1A	99
2	1B	97
3	10	0
4	11	128
5	3	573
6	2	498
7	8	463
8	9	457
9	5	430
10	14	428
11	6	417
12	12	405
13	7	402
14	4	438
15	15	440

At midnight the computer prints out its daily analysis of information obtained from the weather station and from each of the 15 sprinklers. The printout tells how much water the crop has used, how much moisture the field obtained from rainfall or irrigation the previous day, the amount of water depleted from the soil, and the range of earliest and latest recommended irrigation dates. The computer also updates the crucial "safety hours" question: How long can the crop go without irrigation before it is stressed and the yield reduced? (PN-7068)

computer monitors the center sprinkler pivots every 15 minutes, and knows whether they are on, or off due to malfunction or a planned shutdown. The computer also polls a weather station in the field, which informs it of wind velocity, temperature, humidity, and solar radiation. Finally, the computer also knows how much water has been applied to each field, the soil type, and what is being grown.

When the first signal from the power company is intercepted (the power reductions come in 12-percent steps), the computer sends its own signal ordering individual pumps to stop. It automatically selects the fields that are in the least need of water. If second and third signals are received, the computer selects additional fields to take out of irrigation.

There is a manual override in case irrigators wish to continue irrigating a particular crop rather than the one the computer selects.

As the demand for power becomes less, the computer picks up utility company signals and restores irrigation to crops in the sequence most advantageous to total crop production. Although the pumps may have been idle for several hours, the computer has continued to receive information from the weather station and has up-to-date knowledge of crop needs.

"I estimate that we've saved 3 hours a day and 60 miles of driving by relying on the computer," says Duane Foxhoven, farm foreman at the Condon Ranch near Sterling, Colo., where the system was used this past summer.

Top: Condon Ranch foreman Duane Foxhoven programs the computer to change its priorities for turning irrigation pumps on or off in response to utility-company signals during peak power demand periods. Standing by is agricultural engineer Dale F. Heerman, who codeveloped the system. (0983X1219-20)

Above: At one center pivot, Blue (left) services the radio that sends information to the computer on how much water the crop is receiving from irrigation or rainfall, and receives the computer signals that control the sprinkler. Agricultural engineer Harold R. Duke adjusts the gage that takes the rainfall measurements. (0983X1224-5)

The ranch has 15 center-pivot sprinklers that irrigate 2,250 acres. The most distant pivot is about 3½ miles from the computer-control center.

"We used to drive out four to five times a day just to check on the center pivots," says Foxhoven. "Now we can just look at a warning light attached to the computer. When it comes on, we know one or more of the sprinklers has been shut down because of a malfunction or because of a power shortage. A quick check of the computer screen tells us what is happening and where."

In the first year of operation, confidence in the system was so high that during a busy 2-day bean harvest all monitoring was done remotely via the computer.

The system has also resulted in energy savings. Peak demand for power usually occurs on long, hot summer days when energy use is high for air conditioning. Whatever this peak demand is, it determines the electric rate for the entire year. By agreeing to automatic irrigation shutdowns during peak demand, the Condon Ranch's electric bill was 14 percent lower. This amounted to approximately $1,000 in energy savings per pump.

Crop yields also stand to benefit from such sophisticated irrigation scheduling. Under the standard agreement for utility-controlled pivot shutdowns, all power could be shut off every third day and irrigation could not resume until the utility could guarantee enough power for a whole day. The resultant water stress spelled trouble for some crops.

With computer control, the utility requires that no more than 50 percent of power be shut off to pumps at a given time. And pumps can be started back up whenever more power is available. Irrigation scheduling on the Condon ranch, even before computer control, contributed to increasing yields an average 50 bushels per acre during the past 12 years.

The computer on the Condon Ranch is commercially available for about $2,000. Agricultural engineer Gerald Buchleiter at Colorado State University, Fort Collins, worked with Heermann and Duke to develop the software programs that operate Condon's system. These programs would also work on other similar systems. The team is also putting the final touches on a program that indicates the exact position of the pivots. This will make it easier to reach them for making repairs and readjustments.

The test plot of corn at the Northern Colorado Research Demonstration Center is automated for trickle irrigation that is controlled by a computer in the shack; the pond supplies all the project's water needs. (0983X1227-21A)

Dale F. Heermann, Harold R. Duke, and Gerald Buchleiter are located in the Agricultural Engineering Center, Colorado State University, Fort Collins, Colo. 80523.

Plant physiologist Stan D. Wullschleger adjusts a porometer that continuously measures how the corn plant is responding to water deficiency stress. The information feeds into a computer, which automatically triggers irrigation to begin when the plant reaches a predetermined stress level. (0983X1303-21A)

A Computer Answers Plants' Cries for Water

Like children crying out at night for something to drink, plants give signals when they want water. Scientists have known for about a century what these signals are, but only recently has sophisticated equipment been developed to put the information to use.

ARS plant physiologists Edwin L. Fiscus and Stan D. Wullschleger combined an older technology (a mass flow porometer) with new technology (sensitive electronic measuring devices and a computer) to detect when plant stomata are beginning to close—indicating the onset of stress caused by water deficiency.

"By detecting when plants are just beginning to enter a stress phase because of insufficient water, we can halt further progression by irrigating. This gives a potential twofold benefit—greater plant growth because plants never have to be in stress, and decreased water use because it is applied only when the plants indicate they need water, not when an irrigator thinks they need it," says Fiscus, who works in Fort Collins, Colo.

Last summer on small test plots near Greeley, Colo., the scientists harvested an average 146 bushels of corn per acre by using their porometers to trigger a trickle-irrigation system. Plots arbitrarily irrigated every 2 to 3 days averaged 159 bushels per acre, but these plots received twice as much water (33 inches versus 16.5). (Trickle irrigation also contributed to the large increase in water-application efficiency by holding down evaporation.)

The porometers were clamped to corn leaves and attached to sensitive electronic equipment that could take 34 different measurements related to plant stress. Another cord leading to a small computer terminal transferred the measurements from the porometers to the computer every 10 minutes during the day. The computer, using programs written by Wullschleger and Fiscus, analyzed this information at midnight and turned on a pump to supply water to the test plots if stress had been detected.

Fiscus and Wullschleger programmed two different values into the computer to trigger irrigation. One was fairly high and resulted in about 16.5 inches of water being used during the growing season. The other was more conservative and used only 12.5 inches. Both settings produced equal water use efficiencies but the lower setting resulted in corn yields of only 110 bushels per acre versus the 146 bushels for the more liberal irrigation.

Agricultural engineer Allan S. Humpherys programs the Touch-Tone telemetric irrigation controller that can be connected by only one cable to as many surface irrigation stations as necessary. The solar panel charges batteries that power the system. (0782X765-30A)

The versatility of trigger settings may become more important as water costs escalate. Growers could judge whether the potential yield would justify the cost of the water and adjust the settings for more conservative or liberal water use accordingly.

Also, the increased efficiency will help farmers who are limited by law in the number of wells they may drill to expand significantly their irrigated acreage. Using conservative trigger settings in an automatic control system would allow them to increase total production with the same amount of water even though the yield per acre might be somewhat reduced.

Although the tests were run using a trickle irrigation system, any irrigation method that uses electricity for pumping water or regulating flow could be linked to the porometer and results should be comparable, says Fiscus.

Edwin L. Fiscus and Stan D. Wullschleger are located at the Crops Research Laboratory, Colorado State University, Fort Collins, Colo. 80523.

Orchestrating Irrigation Via Touch-Tone Telemetry

Systems for controlling irrigation that are now in use commercially were designed primarily for sprinkler or drip irrigation systems. They do not meet the special needs of surface irrigation installations that are still in use on about two-thirds of the irrigated acreage in the United States. Automation of surface irrigation is worthwhile, however, because water-use efficiencies comparable to those of sprinkler systems can be achieved, and at lower costs using less energy and labor.

Now, a new system that uses Touch-Tone telemetry—like that in modern telephones—can provide surface-irrigators with efficient, low-cost, timer-controlled irrigations.

The system is designed with all the timing, programming, and control functions concentrated into one versatile central controller. The remote field stations contain only the circuitry necessary to decode commands from the central controller and activate the irrigation valves. This design enables the central controller to be quite complex since only one is needed for a given

irrigation installation, while the number of individual field stations can be expanded easily and at small cost.

The system was designed by Herbert D. Fisher, an ARS electronics engineer and Allan S. Humpherys, an ARS agricultural engineer, both at the Snake River Conservation Research Center, Kimberly, Idaho, along with Colorado State University engineer David A. Young, Grand Junction, Colo.

A single, 3-conductor, 18-gauge cable connects all of the field stations to the system's central controller. Each station contains a tone code receiver/decoder which responds to a specific address assigned to that station, in the same manner a telephone responds to its own assigned number by ringing.

Commands from the central controller pass through all field stations and at each station these commands are decoded and compared with that station's address. If the two match, the station opens or closes its irrigation valves. Assigning the same address to different field stations can provide great flexibility in both the amount and pattern of water application.

The new system's central controller can be programmed to control the date and duration of irrigation and the sequence of operation for a large number of remote stations. Information on soil, crop and weather conditions, water supply limitations, and irrigation scheduling can also be programmed into the computer.

The new automated telemetric irrigation controller also has a low power requirement—it can be run on batteries, solar power, or wind power—and has already been successfully tested at three different locations under three different types of automated surface irrigation systems.

According to the system's designers, if the software in the controller is modified, the system could also be used for multiple irrigation cycles such as surge irrigation, a technique gaining increased prominence for efficiency and soil conservation benefits.

Herbert D. Fisher and Allan S. Humpherys are located at the Snake River Conservation Research Center, Rt. 1, Box 186, Kimberly, Idaho 83341.—**Dennis Senft and Lynn Yarris**, Oakland, Calif. ■

Diet Lowers Cholesterol in Athletes

Even if you're physically active, don't assume that you can consume a diet extremely high in saturated fats and rely on exercise to keep your blood cholesterol concentrations low.

When cyclists training for the Olympics consumed a diet with about 12 times as much saturated fat as unsaturated fat, they had average plasma cholesterol concentrations of about 250 milligrams per deciliter (mg/dl). When they switched to a diet with fats composed of three times as much unsaturated as saturated fat, their plasma cholesterol concentrations dropped to about 160 mg/dl. The cyclists lived at the ARS Grand Forks Human Nutrition Research Center while they participated in the 3-month experiment conducted by physiologist Henry C. Lukaski.

Although the cholesterol-lowering impact of replacing much of the saturated fats in a diet with polyunsaturated fats has been recognized for decades, the recent study allayed some remaining doubts. Researchers had wondered if other changes in the diet or changes in exercise, body fatness, or smoking habits may have confounded interpretations of previous studies.

In Lukaski's experiment, the three world-class endurance cyclists maintained constant body weights and top fitness as measured by their bodies' ability to use oxygen. They abstained from drinking alcoholic beverages and smoking, and they consumed carefully controlled diets consisting of conventional foods.

The researchers designed three diets for the experiment, each to be consumed by each volunteer athlete for a 28-day period. One diet was high in complex carbohydrates, such as pasta; one was high in saturated fats such as butter; and one was high in polyunsaturated fats such as safflower oil.

From their analyses of blood samples the scientists observed similarly high cholesterol concentrations when the athletes consumed foods high in saturated fats and foods high in complex carbohydrates.

High-density lipoproteins, which many scientists believe reduce the risk of coronary heart disease, were not changed in concentration by any of the diets. But they also observed that the ratio of high-density lipoproteins to total cholesterol was highest when the athletes consumed diets high in polyunsaturated fats.

Olympic road racing hopeful Davis Phinney in training. Nutrition studies with other Olympic candidates indicate exercise alone cannot lower blood plasma cholesterol concentrations. (Photo by Michael Chritton/*Velo-News*.) (PN-7093)

The levels of circulating triglycerides—other fatty acids also implicated in heart disease—were lowest when the athletes consumed the diet with a high ratio of polyunsaturated to saturated fats.

The research also showed that a formula known as the Keys equation, which was developed to predict changes in plasma cholesterol levels resulting from dietary changes, is as valid for athletes as it has been shown to be for sedentary men.

Henry C. Lukaski is located at the Grand Forks Human Nutrition Research Center, P.O. Box 7166, University of North Dakota, University Station, Grand Forks, N. Dak. 58201.—**Ben Hardin**, Peoria, Ill. ■

Blood Cell "Bridges" Indicate Kidney Damage

Red blood cells from sheep and swine with acute kidney failure are interconnected by "bridges"—extensions of a coat that forms on the cells' surface.

This discovery may have potential as a diagnostic tool for early detection of diseased kidneys in humans. Human beings are higher vertebrates, as are sheep and swine, and may also exhibit these structures at the onset of kidney failure, as well as during the progression of the disease. No tests of the discovery have yet been done with humans, however.

Shirlee Meola, research entomologist, and her associates, veterinary medical officer, Loyd Rowe, veterinary pathologist Sandra Lovering, and medical technologist Ellen Moore, made the discovery at the ARS Veterinary Toxicology and Entomology Research Laboratory, College Station, Tex.

Examination under a scanning electron microscope revealed that the bridges are indeed external structures that apparently form as a result of environmental changes in the blood of diseased animals.

"We don't have the final answer to what causes the bridges to form," says Meola, "but it very likely involves changes in the cell membranes of the red blood cells that cause the cell walls to develop an affinity for certain substances—such as specific ions in the blood—and thus an enhanced affinity for each other."

The bridges range in the shape from long, thin strands to short, thick, ropelike structures. The latter occurred more frequently in sheep with more severe kidney damage.

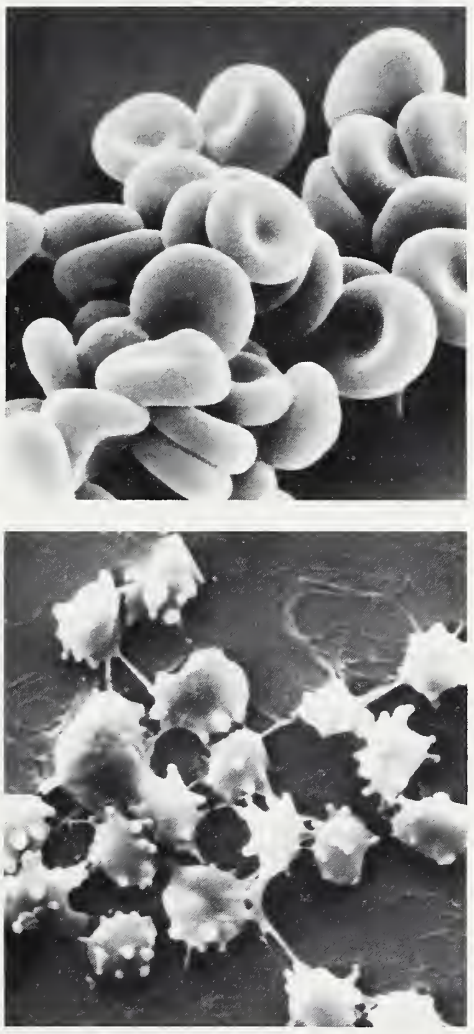
The scientists were able to show that these bridges appeared in large numbers in blood from animals in which even a small portion of a kidney was damaged. In addition, depending upon the severity of the damage, the bridges were found several days prior to any indication of kidney dysfunction by clinical tests. Also, in several sheep that had incurred only slight kidney damage, and whose kidneys regenerated, the cytoplasmic bridges gradually decreased in numbers as the kidneys healed, eventually becoming undetectable.

The scientists have also found that the cytoplasmic bridges form between red blood cells of swine in which kidney damage was experimentally induced.

In a previous morphological comparison of red blood cells between several genera of mammals, including humans, only a small percentage (0.4 to 2.5) of the red blood cells were interconnected by bridges. With the exception of four animals diagnosed as having a heart disease, the remaining animals in that study were considered healthy—none were reported as having a kidney dysfunction. In contrast, 25 to 80 percent of the red blood cells of sheep with kidney damage were interconnected by bridges.

Testing for kidney dysfunction is a cumbersome process, involving measurement of physiological functions such as urine output, in addition to clinical chemistry tests. If proven applicable to humans, this new tool would be an additional quick and simple indicator of kidney dysfunction.

Shirlee Meola, Loyd Rowe, and Sandra Lovering are located at the Veterinary Toxicology and Entomology Laboratory, P.O. Drawer GE, College Station, Tex. 77841.—**Bennett Carriere**, New Orleans, La. ■



Healthy sheep's red blood cells (above) are doughnut-like in shape. Red blood cells from sheep with induced kidney dysfunction are round with knobby projections and are interconnected by cytoplasmic bridges. (Scanning electron micrographs by Shirlee Meola.) (PN-7091, PN-7092)

ARS scientist Shirlee Meola examines her scanning electron micrographs of red blood cells from sheep in the kidney-failure studies. (1283X1665-33A)

Concord grapes ripening under Maryland sun. (0983W1168-10)

Concord Grape Tolerance to Herbicide 2,4-D

Concord grapes tolerate exposure to the herbicide 2,4-D at maximum legal levels in irrigation water. However, multiple direct applications on vineyards, simulating the drift that occurs when nearby ditchbanks or fields are sprayed, can cause serious problems.

In two separate studies, researchers led by ARS plant physiologists Alex G. Ogg and Richard D. Comes, Prosser, Wash., evaluated the response of grapes to 2,4-D in irrigation water, and to direct applications of the herbicide on vineyards.

In the first study, no symptoms of injury were observed on either young or fully developed Concord grape plants sprinkler-irrigated with water containing 0.1 ppm or less 2,4-D, and none of the treatments hurt fruit yield or quality. A level of 0.1 ppm of 2,4-D is permitted in water used to sprinkler irrigate most crops, but no tolerance level has yet been set for grapes.

In the second study, 2,4-D at concentrations of 2.5, 10, and 25 ppm was sprayed directly on established grapes. When applied only 1 year, single direct applications of 2,4-D produced injury symptoms on the foliage, but did not reduce grape yield or quality. Multiple applications of 2,4-D—up to four times per year—at 25 ppm (0.01 pound per acre) during a single year injured vines severely and reduced fruit yield as much as 50 percent.

Multiple direct applications of 2,4-D at all tested concentrations for 3 consecutive years increased injury symptoms and decreased yields as the concentration and number of 2,4-D exposures increased. Yields under these circumstances were reduced as much as 75 percent, primarily by a decrease in the number of clusters and the number of grapes per cluster.

Injury symptoms did not persist, however, from one year to the next, and 2 years after the last treatment with 2,4-D, grape growth and productivity were normal.

Alex G. Ogg and Richard D. Comes are located at the Irrigated Agriculture Research and Extension Center, P.O. Box 30, Prosser, Wash. 99350.—**Lynn Yarris**, Oakland, Calif. ■

Equation Helps Predict Low Birth Weights

Research led by medical doctor Jack Metcoff at the University of Oklahoma Health Sciences Center, Oklahoma City, indicates that inadequate nutritional levels and heavy smoking are among factors involved in low birth weights.

Poverty-level family income does not correlate closely with the risk of low birth weight infants.

The study involved attendees of prenatal clinics at Oklahoma Memorial Hospital, University of Oklahoma, Oklahoma City, some of whom were participants in the state's Special Supplemental Food Program for Women, Infants and Children (WIC).

The researchers took information on the number of prenatal visits to a physician, interval since last pregnancy, sex and gestational age of the infant and the mother's age and level of education, and combined it with biochemical measurements related to birth weights—such as the levels of certain nutrients in blood serum and nitrogen and creatinine in the urine. The resulting mathematical equation successfully explained about 34 percent of the variance in birth weights of the infants. It also showed that the state's WIC program was especially effective among heavy smokers (10 or more cigarettes daily) and women who previously had low birth weight babies.

According to ARS medical officer Harold H. Sandstead, director of the Grand Forks Human Nutrition Research Center, Metcoff's research also shows that the WIC program helps prevent fetal malnutrition in women identified with the greatest risk for giving birth to babies that weigh less than 5½ pounds.

Heavy smokers who received WIC program supplements from midpregnancy to birth had infants who were 7 to 10.5 ounces heavier than infants of women who smoked but did not participate in WIC because of unavailability of openings in the program.

Metcoff, Sandstead, and research chemist C. E. Bodwell of the ARS Human Nutrition Research Center, Beltsville, Md., collaborated in the study that was financed primarily by USDA's Food and Nutrition Service.

Harold H. Sandstead is located at the Grand Forks Human Nutrition Research Center, P.O. Box 7166, University of North Dakota, University Station, Grand Forks, N. Dak. 58201.—**Ben Hardin**, Peoria, Ill. ■

Diet Affects Lamb Chop Flavor

Advances in the genetics, feeding, and management of sheep are likely to result gradually in consumers' finding more lamb at lower prices in their supermarkets. But it is also likely that consumer taste preferences will play a large part in whether those extra lamb chops get eaten.

ARS food technologist John D. Crouse and his colleagues at the Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebr.,

used a taste panel to help determine the influence that diet, breed, sex, and slaughter weight might have on carcass characteristics and flavor of broiled lamb chops.

"Our taste panel assessed the intensities of 11 flavor characteristics rather than the degree to which panelists liked or disliked flavors," says Crouse. "A strong flavor may be desirable to one person and objectionable to another." In an earlier study Crouse and his coresearchers found that only about one time in four did taste panelists favor strong flavors over mild ones.

The panel's consensus: Chops from ram lambs fed a mostly soybean diet had more of a musty flavor and more aftertaste, but these tastes were less intense in chops from rams that had been on the diet longest. In contrast, the panelists judged chops from ewes fed the same diet to be not as intensely musty and muttony as the ram lamb chops. However, these flavors increased in ewe lamb chops with time on feed.

Ram lambs fed out to slaughter weights of about 151 pounds produced meat with more intense gamey and sweet flavors but less intense muttony and musty flavors than did rams slaughtered at about 110 pounds.

Whether lambs were sired by rams of the Suffolk or Columbia breeds included in the study made no appreciable difference in flavor characteristics of the meat. Suffolk-sired lambs weighed more and had higher USDA quality grades than carcasses of Columbia-sired lambs; however, they had lower predicted yields of retail cuts.

Lambs fed alfalfa weighed more than those fed soybean meal. They also had higher quality and yield grades than soybean-fed lambs.

John D. Crouse is located at the Roman L. Hruska U.S. Meat Animal Research Center, P.O. Box 166, Clay Center, Nebr. 68933.—**Ben Hardin**, Peoria, Ill. ■

Update on Threadleaf Groundsel Poisoning

Threadleaf (or woolly) groundsel (*Senecio douglasii* var. *longilobus*), a woody plant common on much of the rangeland in the southwestern United States and Mexico, can be deadly to cattle. Now, ARS researchers have defined under what conditions it is lethal, and when not.

Tests conducted by animal physiologist A. Earl Johnson, Logan, Utah, and chemist Russell J. Molyneux of the Western Regional Research Center, determined that cattle usually die within a few days if they graze large amounts of threadleaf groundsel when it contains high levels of toxic compounds called pyrrolozidine alkaloids (PA). If the level of these compounds is sufficiently high, even moderate grazing over a 2- to 3-week period may result in death, though perhaps not until several months later. However, if PA content is low, cattle can consume small amounts of threadleaf groundsel for long periods of time without apparent harm.

The PA content of threadleaf groundsel may fluctuate wildly during the plants' life cycle, varying as much as tenfold. Earlier studies that established the plants' toxicity provided no specific information based on the plants' PA content.

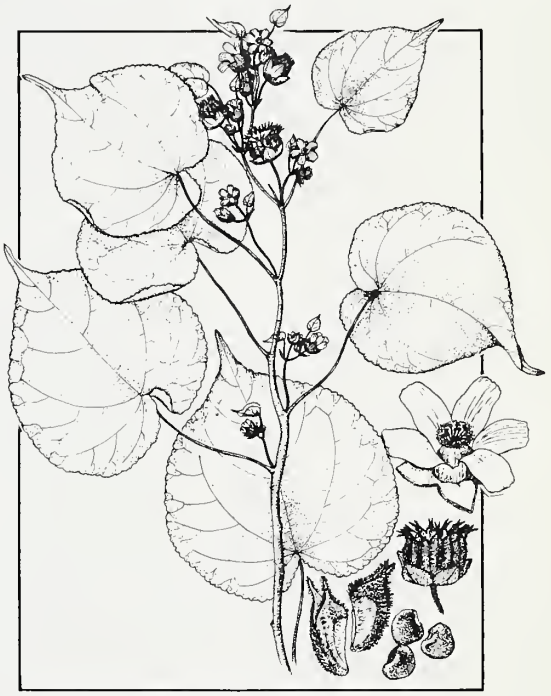
"Our findings emphasize the importance of the time-dose relationship in PA poisoning, and indicate that there is a threshold level of PA that must be exceeded for the poisoning to develop," says Johnson.

"Our knowledge of PA toxicity in cattle remains sketchy because much of it is based on the results of numerous rat studies that have been done," Johnson says. "While reactions relating to PA metabolism in rat livers are likely to be similar to those that occur in the livers of ruminants, the similarity between the two animals ends there. Definitive answers to questions regarding reactions that influence PA toxicity in ruminants must await further experimentation in that class of animal."

A. Earl Johnson is located at the Poisonous Plant Research Laboratory, 1150 E. 14th N., Logan, Utah 84321.—**Lynn Yarris**, Oakland, Calif. ■

Papaya vs. Velvetleaf in the Lab

A compound extracted from papaya seed stops germination and seedling growth of a common cornfield weed but does not affect corn.



Botanical drawing of velvetleaf, *Abutilon theophrasti.* (PN-7065)

In research at the Northern Regional Research Center (NRRC), less than 90 ppm of the papaya compound in water completely inhibited velvetleaf (*Abutilon theophrasti*) seed germination. "Corn was unaffected even at concentrations of almost 150 parts per million of the compound," says ARS plant physiologist Rebecca B. Wolf.

Wolf and research chemist Gayland F. Spencer extracted the compound, benzyl isothiocyanate, from ground papaya seed with solvents in the first study reported from a new search at the NRRC for natural seed germination inhibitors.

"We don't want to suggest that benzyl isothiocyanate would be useful or practical in the field since we have no knowledge of that sort of application," Wolf says. Greenhouse and field experiments are necessary to obtain further information on dosage, longevity, and side effects.

In soybean tests, the 90 ppm papaya compound concentration that completely stopped velvetleaf germination also reduced soybean germination 28 percent. A 60-ppm concentration killed 3-day-old velvetleaf seedlings, and reduced weed seed germination 72 percent. It reduced soybean germination 11 percent.

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"Many plants produce chemicals that are harmful to other species and help to reduce competition in their natural habitats," Wolf says. The benzyl isothiocyanate found in papaya (*Carica papaya*) is found also in the cabbage and nasturtium families.

Velvetleaf is economically harmful in Missouri, Illinois, Indiana, Ohio, Kentucky, Tennessee, the Virginias, and parts of adjoining states.

Rebecca B. Wolf and Gayland F. Spencer are located at the Northern Regional Research Center, 1815 N. University, Peoria, Ill. 61604.—**Dean Mayberry**, Peoria, Ill. ■

Bur Buttercup's Poison Found

The May 1983 issue of *Agricultural Research* reported that a small rangeland plant, bur buttercup, had recently been found to be highly toxic and lethal to sheep.

Now, Ronald J. Nachman, ARS chemist at Berkeley, Calif., has identified the chemical compound ranunculin as the major toxic constituent of bur buttercup (*Ceratocephalus testiculatus*). Ranunculin is notorious as the lethal poison present in many species of true buttercup plants.

Nachman analyzed samples of the weed at various stages of growth to determine those with the greatest concentrations of the poison. "The highest concentrations of ranunculin proved to be in the early flower stage, when the toxin accounted for 2.3 percent of the plant's dry weight," he says.

Animals on a normal grazing regimen or receiving some supplemental feed are not likely to eat enough bur buttercup to be poisoned, according to veterinarian John D. Olsen, Logan, Utah. However, Olsen says, "Just a little over a pound of green plant is enough to kill a 100-pound sheep."

An annual appearing between March and May, the small, gray-green, woolly bur buttercup now grows in Colorado, Idaho, Nebraska, Nevada, Oregon, Utah, and Washington, and appears to be spreading rapidly.

John D. Olsen is located at the Poisonous Plant Research Laboratory, 1150 E. 14th N., Logan, Utah 84321. Ronald J. Nachman is located at the Western Regional Research Center, 800 Buchanan St., Berkeley, Calif. 94710.—**Lynn Yarris**, Oakland, Calif. ■

New Hydrologic Soil Classification

Predicting the influence of land management practices on agricultural soil-water properties should be a more accurate endeavor now that new hydrologic classifications of these agricultural soils have been developed.

Hydraulic engineer Donald L. Brakensiek, Boise, Idaho, and hydrologist Walter J. Rawls, Beltsville, Md., have designed a system to classify soils for soil-water retention and infiltration rate based on data compiled by the USDA's Soil Conservation Service (SCS) and other federal agencies. The scientists analyzed more than 5,000 soil samples, and have included nearly 1,200 soil types from 34 states in their new classification system.

The soil-water retention characteristic developed by Brakensiek and Rawls is based on the known range of soils' potential to attract and hold water. The infiltration characteristic is based on soil porosity and how it and the soil's water-attracting ability change under different management practices.

The current most widely used hydrologic soil classification system represents the minimum infiltration rates of soils, and does not account for the effects of management practices on given soil profiles.

Brakensiek and Rawls' new classifications are for soils that have been cultivated. They are now developing similar classifications for rangeland soils.

Donald L. Brakensiek is located at Patti Plaza, Suite 116, 1175 South Orchard, Boise, Idaho 83210. Walter J. Rawls is located at the Hydrology Laboratory, Bldg. 007, BARC-West, Beltsville, Md. 20705.—**Lynn Yarris**, Oakland, Calif. ■